Effect of regular Tai Chi and jogging exercise on neuromuscular reaction in older people

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Abstract

Objectives: to investigate the effects of regular Tai Chi (TC) or jogging exercise on neuromuscular reaction in older people.

Design: cross-sectional study.

Setting: university biomechanics laboratory.

Subjects: 21 long-term elderly TC practitioners were compared with 18 regular elderly joggers and 22 sedentary counterparts.

Measurements: electromyography (EMG) was used to detect the neuromuscular reaction of the leg muscles to an unexpected ankle inversion perturbation. The latency of the muscles, which was defined as the time that the moment of perturbation began to the onset of the EMG response, was evaluated.

Results: a one-way ANOVA revealed that there were significant differences in the latency of the rectus femoris (R) and anterior tibialis (T) muscles between the three groups, but that there were no differences in the latency of the semitendinosus (S) and gastrocnemius (G) muscles. Further tests indicated that the R and T muscles in the TC and jogging groups were activated significantly faster than those in the control group. No significant difference was found for the muscle onset latencies between the TC and jogging groups.

Conclusion: maintaining information processing speed during ageing is important, because of the role that it plays in many everyday events. The R and T muscles in the regular TC and jogging groups showed faster responses to unexpected ankle inversion perturbations, which is helpful for the timely correction of postural disturbances, than those in the sedentary control group.

Keywords: elderly, jogging, muscle latency, neuromuscular reaction, Tai Chi

Introduction

As a traditional Chinese exercise, it is widely accepted that Tai Chi (TC) has particular benefits for postural stability in older people by acting on a number of sensorimotor systems that contribute to postural control. A number of studies have shown that TC practitioners have a better balance capacity, proprioceptive function, and muscle strength [1–3]. However, in addition to acute proprioception and adequate muscle strength, the prevention of falls also depends on the timely initiation of an appropriate postural response to control the body’s centre of mass once a displacement occurs [4]. Greater postural sway, decline in the ability to regain balance by taking a rapid step [5], and the increased incidence of falls that are observed in older people suggest that they may be slower in correcting postural disturbances [6]. To date, the effect of regular TC practice on postural reaction has not been reported.

Postural responses have been studied in standing subjects by provoking sudden rotational perturbations of the ankle and evaluating the latency, magnitude and frequency of the trunk and lower extremity EMG activity [7–10]. Among these variables, the latency of muscular activation, which is defined as the time from the first moment of perturbation to the onset of the EMG response, is one of the most common parameters to be evaluated. Muscle latency provides information about the speed of neuromuscular reaction, which is an important link in postural control. Through EMG analysis, the measurement of the muscle response to unexpected perturbations has shown significant differences of 7–10 ms in lower extremity muscle latencies in old versus young populations [11–13], and in older fallers versus non-fallers [14]. A delay in the latency of muscle activation hinders the onset of postural response, which could result in insufficient correction of a postural perturbation to avoid a fall. Therefore, the maintenance of information processing speed during ageing is important because of the role that it plays in many everyday events, such as operating an automobile safely or restoring balance after a near fall.
Hu and Woollacott [8] identified that multisensory balance training has an effect on the optimisation of the muscle and the movement characteristics of postural response in older adults. After 15 days of multisensory balance training, the postural responses of the training group seemed to have a greater similarity to those of younger adults than the control group. TC movements contain many training components for balance control [15], such as the shifting of body weight from a unilateral to a bilateral position, and changing between dual-stance and single-stance manoeuvres. This study examined the influence of long-term regular TC practice on neuromuscular reaction in older subjects, and compared this with the influence of regular jogging, which is a popular exercise in the elderly. This information will be helpful in exploring the mechanism by which TC practice improves postural control.

Method

Subjects

Community-dwelling adults who were aged 60 years and over were recruited by means of a questionnaire with a complementary interview on the practice of physical and sporting activities. Potential subjects were not included in the investigation if they reported any of the following: neurological diseases that impair mobility (e.g. Parkinson’s disease, stroke), dementia (defined as a Mini-Mental State Examination score of <24), cancer, cardiovascular disease that is symptomatic during moderate exercise, poorly controlled hypertension (BP >166/96 mmHg), and use of specific medications that are known to impair balance (e.g. neuroleptics or benzodiazepines).

The TC practitioners came from three TC clubs, which have hundreds of members who perform TC on a daily basis. Jogging is one of the most common forms of exercise in older people, and was thus selected as a contrast to TC exercise. Joggers were recruited from a large health centre for older people where active individuals participate in regular exercise programs. The joggers engaged in regular jogging exercise, and occasionally also performed other physical activities, such as swimming and bicycling. The sedentary control group was composed of 10 women and 12 men who had not practised any regular exercise activity in the past 5 years.

The study was approved by the regional ethics committee, and all the participants gave their written consent before the study.

Instrumentation

Neuromuscular reaction was assessed by detecting the muscle latency of the leg muscles to an unexpected perturbation on the ankle in the medio-lateral plane.

Using the design that has been reported in many related studies [16–18], a customised trapdoor was constructed with two movable platforms to stimulate an ankle inversion situation (see Appendix 1 available as supplementary data on the journal website www.ageing.oupjournals.org). In this test, the amplitude of the completed tilt of the platforms was kept constant at 18°. The onset and terminating signals of the tilting could be collected simultaneously with EMG signals.

A Bagnoli-8 EMG system (Delsys, USA) was used to collect surface EMG signals in four muscles on the right leg of each subject: the rectus femoris (R), semitendinosus (S), anterior tibialis (T) and gastrocnemius (G) muscles. The raw EMG signals were sampled at 1000 Hz by Labview Software (National Instruments, USA) and stored in a computer for off-line data reduction.

Procedures

The subjects were given two practice trials on the trapdoor to familiarise them with the test process. The EMG electrodes were then secured over the centre of the muscle bulk of the selected right leg muscles, and the locations were verified by manual test and voluntary contractions. The subjects were asked to stand barefoot on the perturbation trapdoors with the body weight evenly distributed between both feet. The axis of rotation of the trapdoors was just medial to the sole of the feet. One of the trapdoors was released when the muscles were relaxed, which was deemed to be when the EMG signals showed the baseline resting level as confirmed by the examiner. The computer program sampled the EMG data from 500 ms before the onset of tilting to 1 second after the inversion moment. To reduce any anticipatory effects, both feet were randomly tilted at least seven times each. The EMG signals that were responses to the tilting of the right door (a direct reaction) were analysed.
EMG data reduction

The raw EMG signals were rectified, and the time course of the EMG activity was measured using a cursor on the computer screen (1 sample = 1 ms), which was referred to the movement of the onset of the trapdoors. The onset latency was the time interval in milliseconds (ms) between the initiation of the trapdoors and the first rising response of the EMG burst from the baseline to clear activity, which was determined by visual inspection (Figure 1). The start of the electric motor driving the trapdoors sometimes produced a small artefact in the EMG trace, and therefore any activity that occurred before 45 ms after the onset of the trapdoor was ignored, as the earliest reflex activity would occur after that time [19]. To reduce observer bias, the data for the three groups were analysed blindly and simultaneously by the same investigator.

Test–retest reliability measurements

Repeatability measurements were conducted before the formal testing protocol. The test–retest reliability coefficients of the trapdoor time and different muscle latencies were obtained from another 10 subjects who underwent the two assessments on separate days according to the testing procedure that has been described.

Statistics

Except for gender (categorical variable), a one-way analysis of variance (ANOVA) was used to determine the significant differences of the baseline characteristics and muscle latencies between the groups. Post hoc Tukey tests were performed when necessary to isolate the differences, and the probability level of $P < 0.05$ was accepted as the criterion of statistical significance. Interclass correlation coefficients (ICC) were used to analyse the repeatability of the measurements. The difference in the proportion of gender between the three groups was compared using the Kruskal–Wallis non-parametric test.

Results

Table 1 gives a general description of the subjects. No difference was noted in age, weight, height, ratio of gender, or education experience across the three groups. The TC practitioners and joggers had similar physical levels: there were no differences in their exercise experience or duration. A small percentage of the subjects in the three groups reported having chronic disease, but all were receiving regular treatment.

Repeatability analysis showed that all the measures of muscle latency had a moderate to high test–retest reliability, with ICC that ranged from 0.68 to 0.94.

The mean onset latency for the R, S, G and T muscles in different groups is shown in Table 2. The ANOVA test revealed that there were significant differences in the latency of the R and T muscles between the three groups ($F = 4.524, P = 0.015$ for the R muscle; $F = 4.670, P = 0.013$ for the T muscle), but that there were no differences in the latency of the S and G muscles ($F = 2.265, P = 0.113$ for the S muscle; $F = 2.265, P = 0.113$ for the G muscle).

Figure 1. Representative EMG recording from the lower limb muscles after a sudden inversion perturbation of the ankle joint in a standing subject. The trapdoor release coincides with the elevation of the trapdoor onset signal.
for the same forward or backward translation, the distance was 5.08 cm and the velocity 12.7 cm/s in the study by Studenski et al. [14], whereas Hu and Woollacott [8] carried out the perturbation at a velocity of 31 cm/s and amplitude of 2.8 cm. By comparison, the characteristics of the perturbations imposed in the ankle frontal plane are more consistent in many related studies that involve a trapdoor with a 30° tilting angle to stimulate ankle inversion rotation [16–18]. Lateral perturbations are common in everyday life, and the experimental simulation setting is comparatively easy to control. Therefore, in this study we chose this model to observe postural responses. As the subjects were elderly, the tilting angle was reduced to 18° to avoid causing falls. The subjects in this study did not use a grasp or step strategy to keep their balance. They counteracted such perturbations depending on ankle and hip strategies.

The first muscular reaction measured after sudden inversion of the ankle is in the peroneal muscles, which are stretched. It has been suggested that these muscles play a role in inversion injury protection [18]. The emphasis of this study was to understand the automatic postural responses (medium and long muscle latency) to lateral perturbation that occur in the other muscles of the lower extremity, and thus the response of the peroneal muscles was not included in this study.

Ten to 20 ms after the response of the peroneal muscles, an EMG response can be measured in the thigh muscles while EMG signals in the unilateral anterior tibialis muscle are seen at the same time or later than the peroneal signal [18, 25, 26]. The loaded leg showed flexion of the hip and knee and dorsiflexion of the ankle after sudden inversion of the ankle [26]. Obviously, this is achieved by the contraction of the quadriceps, hamstrings and tibialis muscles. The objective of this activation strategy seems to be to control stability and lessen the load on the inverting foot. From the results of this study, the R and T muscles in the TC and jogging exercisers showed faster responses than those in the control subjects, which was obviously helpful for the timely correction of postural disturbance. For the S muscle, the onset time in both exercise groups showed a clear trend for being greater than that in the control group, although the differences did not reach significant levels. As the antagonist, the onset of the G muscle was the slowest of the four muscles across the three groups of subjects, which should belong to the category of long-latency muscle response in gaining postural stability. There was no difference between the exercisers and sedentary controls in the activation of this muscle.

Although different kinds of exercise may have different effects on proper balance, exercise training has been widely

### Table 1. General description of the subjects (mean ± SD)

<table>
<thead>
<tr>
<th></th>
<th>TC group (n=21)</th>
<th>Jogging group (n=18)</th>
<th>Control group (n=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>66.2 (5.1)</td>
<td>65.2 (3.0)</td>
<td>64.9 (3.2)</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>13/8</td>
<td>11/7</td>
<td>12/10</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>163.6 (7.9)</td>
<td>164.1 (9.0)</td>
<td>164.1 (7.9)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.8 (10.0)</td>
<td>66.1 (13.4)</td>
<td>69.5 (10.8)</td>
</tr>
<tr>
<td>Education (years)</td>
<td>13.0 (2.7)</td>
<td>12.7 (2.4)</td>
<td>12.9 (2.7)</td>
</tr>
<tr>
<td>Exercise experience</td>
<td>7.5 (2.8)</td>
<td>6.8 (2.3)</td>
<td>–</td>
</tr>
<tr>
<td>Duration (min/day)</td>
<td>72.6 (18.7)</td>
<td>69.4 (14.2)</td>
<td>–</td>
</tr>
<tr>
<td>Disease status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arthritis</td>
<td>12%</td>
<td>11%</td>
<td>14%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>4.2%</td>
<td>3.7%</td>
<td>6.5%</td>
</tr>
<tr>
<td>Hypertension</td>
<td>5.3%</td>
<td>6.4%</td>
<td>8.2%</td>
</tr>
</tbody>
</table>

M, male; F, female.

### Table 2. The onset latency (ms) of different muscles among the three groups

<table>
<thead>
<tr>
<th></th>
<th>TC group</th>
<th>Jogging group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectus femoris</td>
<td>84.21 (10.23)</td>
<td>83.08 (10.33)</td>
<td>91.70 (10.02)</td>
</tr>
<tr>
<td>Semitendinosus</td>
<td>83.90 (11.02)</td>
<td>81.03 (10.43)</td>
<td>88.06 (10.25)</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>91.59 (13.19)</td>
<td>95.30 (13.20)</td>
<td>96.31 (8.36)</td>
</tr>
<tr>
<td>Anterior tibialis</td>
<td>81.91 (8.20)</td>
<td>81.69 (9.87)</td>
<td>88.52 (6.67)</td>
</tr>
</tbody>
</table>

Mean ± SD.

\(F=1.082, P=0.346\) for the G muscle. Further tests indicated that the R and T muscles in the TC (\(P=0.03\) for the R muscle; \(P=0.02\) for the T muscle) and jogging groups (\(P=0.01\) for the R muscle; \(P=0.02\) for the T muscle) were activated significantly faster than those in the sedentary control group. No significant difference was found for the muscle onset latencies between the TC and jogging groups.

### Discussion

The prevention of falls depends upon the timely initiation of an appropriate postural response. Although situations jeopardising balance occur in all age groups, postural adjustments in older adults have been characterised as lacking the speed and the adroitness that are necessary to ensure the recovery of stability [20, 21]. Several studies have shown that exercise may counteract some parts of the age-related decline in postural responses [8, 22, 23]. Our data supported these findings, with the onset times of the R and T muscles across the three groups of subjects, which should belong to the category of long-latency muscle response in gaining postural stability. There was no difference between the exercisers and sedentary controls in the activation of this muscle.

Ten to 20 ms after the response of the peroneal muscles, an EMG response can be measured in the thigh muscles while EMG signals in the unilateral anterior tibialis muscle are seen at the same time or later than the peroneal signal [18, 25, 26]. The loaded leg showed flexion of the hip and knee and dorsiflexion of the ankle after sudden inversion of the ankle [26]. Obviously, this is achieved by the contraction of the quadriceps, hamstrings and tibialis muscles. The objective of this activation strategy seems to be to control stability and lessen the load on the inverting foot. From the results of this study, the R and T muscles in the TC and jogging exercisers showed faster responses than those in the control subjects, which was obviously helpful for the timely correction of postural disturbance. For the S muscle, the onset time in both exercise groups showed a clear trend for being greater than that in the control group, although the differences did not reach significant levels. As the antagonist, the onset of the G muscle was the slowest of the four muscles across the three groups of subjects, which should belong to the category of long-latency muscle response in gaining postural stability. There was no difference between the exercisers and sedentary controls in the activation of this muscle.

Although different kinds of exercise may have different effects on proper balance, exercise training has been widely
accepted to be one of the best ways to improve the stability of older people by acting on a number of sensorimotor systems that contribute to postural control [8, 22, 27, 28]. Both TC and jogging exercise are common physical activities in older people, but their characteristics are obviously different. TC exercise includes a series of individual graceful movements, and is known for its particular benefit to balance function, whereas jogging is a kind of cyclic repetitive action and contributes to maintaining muscle strength and cardiorespiratory fitness. From our present and previous study [29], we concluded that there might be no significant differences in muscle function between regular elderly TC practitioners and elderly joggers. Both the long-term practice of TC and jogging produced a positive impact on muscle strength, endurance and muscle reaction time. However, the proprioceptive function in the TC group was found to be better than that in the jogging and sedentary control groups [3]. Therefore, we deduced that the beneficial effects of TC exercise in retaining proprioception in the elderly might be a considerably more important factor why TC exercise improves balance control in the elderly.

The limitation of the study was the cross-sectional design. Such an observational study unavoidably includes the possibility that residual confounding may have contributed to findings, although we tried to compensate for the weakness by well-controlled subject screening. This is especially true when considering the subjects’ health status (the subjects in the control group seemed to be marginally weaker). A randomised controlled study is currently being conducted in our laboratory, and will provide clearer information about the effects of TC on neuromuscular reaction in older people.

This is one of the first reported studies to show that regular older TC practitioners and joggers both have faster muscle reaction to unexpected perturbations, which might benefit the elderly in maintaining proper postural control.

**Key points**
- Postural adjustments in older adults have been characterised as lacking the speed and the adroitness that are necessary to ensure the recovery of stability.
- This study investigated the effects of regular TC or jogging exercise on neuromuscular reaction in older people.
- The regular older TC practitioners and joggers both have faster muscle reaction to unexpected perturbations, which might benefit the elderly in maintaining proper postural control.

**References**
Older hospitalised patients at risk of malnutrition: correlation with quality of life, aid from the social welfare system and length of stay?

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Abstract

Background: malnutrition is regarded as a major risk factor for complications and delayed recovery in hospitalised elderly patients.

Objective: to examine the prevalence of malnutrition in hospitalised elderly patients and evaluate simple clinical screening criteria. To investigate whether malnutrition was related to lack of care from the health care or social welfare system, quality of life and hospital length of stay (LOS).

Setting: non-acute geriatric hospital.

Subjects: 294 elderly patients admitted for rehabilitation after acute hospital care; 244 patients were available for assessment.

Methods: questionnaire interview about nutrition, social network and quality of life. Anthropometric and biochemical measurements, assessment of physical and cognitive function, recording of LOS, discharge destination and diagnosis.

Results: 126 patients (51.6%) were at risk of malnutrition using the criteria of body mass index <22 kg/m2 and/or weight loss ≥5%/6 months. Poor quality of life in women (P<0.04) and loss of the health of a spouse (P<0.02) correlated with weight loss. No differences were found in patients at risk regarding LOS, discharge destination, or aid from the social welfare system.

References


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